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OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PLATE V

GEORGE HORACE TIDY, 1915-1942

—Photograph by Ashley and Crippen

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GEORGE HORACE TIDY

By R. K. YOUNG

(With Plate V)

IN the death of Lieutenant George H. Tidy, who was killed in the battle of Java, March 1942, astronomy and science lost a promising young scholar.

George Horace Tidy was the elder son of Olga Louise Dettmann and the late Horace Tidy. He was born in Toronto May 19, 1915, and his preliminary education was received at Western Avenue Public School and Humberside Collegiate Institute. On his graduation as gold medallist from the latter institution in 1934, he obtained three matriculation scholarships for the Arts course in the University of Toronto, the first and second Edward Blake and the first Moses Henry Aikins. He was enrolled in Victoria College and throughout his four years of University life was known as an outstanding student. During his last year at the University he specialized in astronomy, and upon graduation in 1938 was appointed assistant in the David Dunlap Observatory. He became a member of the Royal Astronomical Society in 1939.

From September 1938 to July 1940 Mr. Tidy was engaged in observation of stellar spectra with the 74-inch reflector and in their measurement and reduction for radial velocity determinations. He possessed great acuity of vision and his measures for radial velocity have always proved uniformly reliable. He was anxious to pursue his studies in astronomy and obtain his Doctor's degree, looking forward to the study as his life's work. With this end in view he had planned to continue his researches at Harvard Observatory. The war interrupted this plan. After a special course at the University of

Toronto in radio communications, he enlisted in the Royal Canadian Navy. On August 20, 1940, he left Toronto for Halifax, en route to England, being on loan to the British Navy. After some further special training at Portsmouth he was placed in charge of the airplane locator instruments when the "luftwaffe" staged an aerial blitz. In February 1941 he was appointed to H.M.S. *Exeter* and was on that ship until she was sunk off Java.

At sea for more than six months he was very happy aboard ship and wrote many times of the "glorious adventure", of his having visited almost every part of the globe, freezing in the Icelandic waters and melting in the tropics. He also wrote often of the grimness of the naval struggle.

Lieutenant Tidy while at the University was a member of the Hart House Glee Club and was very fond of classical music. He had collected a wonderful library of symphonic records which he would never allow anyone but himself to touch. While on board the *Exeter* he had bought himself a phonograph.

He was skilful at drawing and was a creditable painter. On more than one occasion he carried off prizes offered by the Canadian National Exhibition which entitled him to free tuition at the College of Art, which he attended.

Mr. Tidy was always interested in the stars and when a small boy would sit out in the garden on summer nights with a star map on his knees and a flashlight at hand and would gaze at the heavens, thus making himself familiar with the constellations. He constructed for himself a small telescope which he used in these studies.

He attended St. Mary Magdalene's Church, of which he was a member since a young lad. He was a member of the church choir and also a senior server. Besides his mother, a brother William and a sister Carol survive.

David Dunlap Observatory,
Richmond Hill, Ont.

TRUE ANNIVERSARIES

By C. E. White

THE *Standard Dictionary* defines an anniversary as "a day separated by an exact number of years from some past event". The duration of an event may be less than an hour on some Gregorian date. If we regard the year as 365 and one-quarter days in length, the yearly return of the hour of the event may fall on the date preceding the date of the event or on the date following that date. An anniversary so determined might be called the true anniversary of the event.

Since George Washington was born February 22,[1] 1732, the first anniversary of the event was determined by 366 days. Now if we assume that he was born during an early a.m. hour, the true anniversary would be February 21 and the next two anniversaries would fall on February 21. Three years out of four the yearly return of the time of the event was on February 21 until 1800, or during his lifetime. From 1732 to 1932 is 200 years, but in that interval the Julian calendar has been advanced two more days to make it agree with the Gregorian while the difference for 200 years is one and a half days. Hence 12 hours should be subtracted from the time of birth in 1732 to get the yearly return of the time of the event in 1932. Hence, the true anniversary in 1932 would be February 21. If he was born at a late p.m. hour only one return of the event would be on February 21. From these observations we make deduction that twins born one before midnight and the other after on a date between February 29 and February 28 of the preceding year should be given the first date for a birthday—it can also be shown that if the birth was after February 29, not more than twelve months after, the latter date should be given. Since the year 2000 is a leap year, the lappings mentioned above would not be affected during the life

[1]The literature that favours the World Calendar reform gives much emphasis to the possibility of Monday holidays and a few advocate honouring the memory of Washington on February 11 because February 11 was the date of his birth, old style, and because February 11 would come on Saturday. They fail to observe that the anniversary of February 11, 1732, is for any year of this century, February 9.

of the individual whose life span is somewhere between 1900 and 2100.

The following is a short short story made shorter. The stork dropped my childhood's sweetheart just before midnight, Oct. 24, 1868, and just after midnight of the same night and in the same school district, it dropped me. If we had been born for each other, as predicted, we could have let Oct. 25 be our birthday, but had we been born one year sooner, Oct. 24 would have been our common birthday anniversary. In the one case the year preceding the fourth anniversary was 366 days long while in the other case the year preceding the first anniversary would have been 366 days long. If we had been born two years earlier, I could have eaten birthday cake[2] with her two years out of four and if we had been born one year later, we could have eaten birthday cake together two years out of the four until 1900.

Let us be a little more exact and measure each year by 365 days, 5 hours, 48 minutes and 45 seconds which is 1.02 seconds less than its true length. Hence four Julian years is approximately 45 minutes longer than four Gregorian years and $4n$ Julian years would be $3n/4$ hours longer than $4n$ Gregorian years.

Assuming that Mary was born at 11 p.m. and that I was born at 1 a.m., it is easy to see that the eighth yearly return would be Oct. 24, 9.30 p.m. and Oct. 24, 11.30 p.m. For the year 1896, when n was 8, the yearly return of the time of the two events were 5 p.m. Oct. 24 and 7 p.m. Oct. 24. Since 1900 was not a leap year, it is easy to show that the yearly return of the time of the events for 1901, 1902, and 1903 was an hour in Oct. 26. Because 1900 was not a leap year it was not possible for the anniversary of my birth to fall on Oct. 24 two years in succession. For this to happen,

$$3n/4 > 7,\ 3n > 28, \text{ or for } n = 10,$$
$$\text{or } 4n = 40, \text{ but } 1868 + 40 = 1908.$$

However, for many similar problems, especially for this century, it

[2]The proposal of the World Calendar Association would cause the anniversary of any birth to come on the same day of the week each year; and, as Sunday is the most convenient day for birthday surprises, the approximately one-seventh would enjoy more of the surprises than the other groups.

would be possible for two or three consecutive returns to come on the day preceding.

The above was written to give something to think about, especially when you are tempted to oppose a change in the calendar because it would apparently call for a change of one day in the anniversary of your birth—without taking time out to compute, as I have, wouldn't it better to leave it where it is?—and it was also written to correct an erroneous statement in my article, "Calendar Reform," in this JOURNAL, p. 244, vol. 35.

CALENDAR MNEMONICS AND MNEMONIC CALENDARS

By C. E. WHITE

A VERSE or other device that assists the memory is a mnemonic. In astronomy we have the name M. Vem J. Sun which assists in remembering the names of the planets and their order from the sun. Roy G. Biv is a similar mnemonic for remembering the primary colours in their order. Bode's Law is a mnemonic to determine the approximate distances of the planets.

Calendar mnemonics were used in the eighth century and probably long before. Venerable Bede used a number of mnemonics in his almanac, published during the eighth century. His almanac was written in Latin and it very likely contained the Latin form of the jingle:

> Thirty days hath September,
> April, June and November;
> All the rest have thirty-one,
> Excepting February alone,
> Which hath twenty-eight in fine,
> Till leap year gives it twenty-nine.

Or the shorter form:

> Thirty days hath November,
> April, June, and September;
> February hath twenty-eight alone
> And the rest all have thirty-one.

The latter first appeared in English in 1572.[1]

Practically, the first two lines give sufficient aid to the memory because anyone not a child, would not be puzzled as to the number of days in February and it would be implied that the month in question would have 31 days if it be not one of the four mentioned in the couplet. It is easier to remember that the odd months of the first seven have 31 days each and that the even months of the last five, beginning with August, each has thirty-one days. To assist in remembering his "regulars," or month numbers, Venerable Bede gave the following mnemonic:

> April hath to link with July
> And merry new year with October comes by;
> August for Wednesday, and Tuesday for May,
> March, November and Valentine's day;
> Friday for June, and December
> For Sunday and Sunday for September.

The above puzzle is easily solved by observing, for example, that Friday is the sixth day of the week and that six is the regular for June.

For the purpose of determining the dominical letter for each month of the year the following couplet is used.

> At Dover dwells George Brown Esquire
> Good Christopher Finch and David Fryar.

Where A represents the dominical letter of January or the year, D will represent the dominical letter of February, etc., and the twelve dominical letters would be

ADDGBEGCFADF.

Now if the dominical letter of the year be C, we would advance each of the above letters two places and get:

CFFBOGDEACFA.

The above couplet could also be used to derive Elliott's month numbers

144, 025, 036, 146

since A is the first letter of the alphabet, D the fourth, etc.

[1]See Article, "Thirty Days Hath September", by Wade Paston, *Journal of Calendar Reform*, September 1938.

While I was doing research work relative to the calendar, I observed that 90 volumes of the long-time publication "Notes and Queries" took up much space on the shelves in the reading room of the I.U. general library. Thinking that something pertaining to calendars might be discovered in them, I consulted the indexes and found a number of references to calendars and mnemonic calendars. Looking up one of the references, I learned what a mnemonic calendar is.

If one can remember the dates of the first Sunday of each month of the year he can easily find the date of any Sunday of the month, and knowing the date of Sunday it is easy to determine the date of any other day of the week. A mnemonic calendar is a verse that will help in remembering the Sunday dates. The following by A. E. Keats for 1874 is an example:

> For once one finds three several beaux
> Find two and six for 16 goes.

Nonsensical, but Keats said he found it a great comfort to be always independent of an almanac. Amateurs might have trouble interpreting the above. "For" is bad spelling for *four*; where there is a "once" there is a *one*; anyone that knows his numbers knows what *one, two, three, six*, 1 and 6 means: the "fi" in *finds* and *find* is also in *five*, it requires but little effort to see *seven* in "several"; "beaux and goes" is put in for the sake of a jingle and the word "and" is used to connect things up. Any one wishing to use this mnemonic can do so in 1942.

The following by St. Swethen is a mnemonic for 1878:

> Six threatening thrashers warn
> Seven fife men to shun;
> Seven fought once with six
> And three pence won.

Anyone that cares to, can solve the mnemonic puzzle and use it in 1946.[2]

T. S. A. commenting on Keats's two lines said: "I think he could not have been acquainted with the old familiar mnemonic distich:

[2]Anyone wishing to solve other such puzzles can find them in "Notes and Queries."

At Dover dwells John Brown, Esquire
Good Christopher Finch and David Fryer."[3]

This can be used when the date of the first Sunday is known. If the date be Jan. 1, A is 1, B is 2, C is 3, etc. This will hold when the first of January falls on other days of the week; thus, if A is 3, B is 4, C is 5, D is 6, E is 7, F is 1 and G is 2. Thus T. S. A. made out of the above mnemonic a perpetual mnemonic calendar. In this method it was necessary to determine the date of the first Sunday of the year from the date of the last Sunday of the preceding year or by some similar method.

In "Notes and Queries," 1874, Carl Dean gave a method of finding the day of the week. The first of January would fall for any year by formula, and he then gives a mnemonic to determine the day of the month that the same day of the week will fall on for each of the other months:

New Year's day and October 1 being reckoned
In July and in April that day will be second, etc.

I regarded the above as marking the transition from mnemonic calendar to the perpetual calendar of the formula type until I read A. E. B.'s criticism.

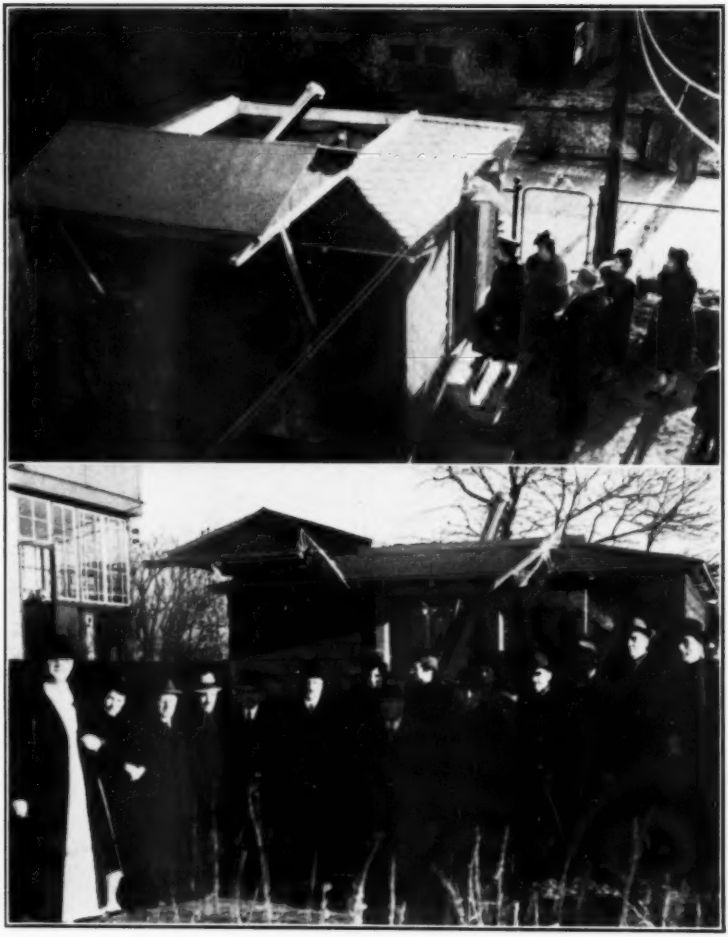
In the same volume, I found this by A. E. B.: "Upward of a score of years ago (1851) when I was contributing to the First Series I took some pains with a mental almanac,[4] as old as Venerable Bede, which I explained and modified to embrace all cases, all years, all centuries and all varieties of old and new styles, and now in 1874 after half a hundred volumes of "Notes and Queries" have been published, I have encountered by accident the pains taken by your correspondent, Carl Dean, to deprive that venerable mental almanac of all its best features in order to produce a worthless *caput mortuum* of his own." In what followed he points out the imperfections in Dean's method.

[3]This has been in the "Book of Common Prayer" for centuries.

[4]Had it not been for this criticism, I probably would not have learned of the perpetual calendar derived by Venerable Bede during the eighth century or someone before his time because I was looking for calendars and not almanacs.

Bloomington, Ind.

PLATE VI



AT THE INAUGURATION OF THE VILLE MARIE OBSERVATORY

—Photographs by G. A. Lefevriere

Above, from left to right: Mrs. D. Garneau, Mrs. J. E. Guimont, F. J. DeKinder, Mrs. Desjardins, Miss T. Egan, Francois, son of Mr. Garneau.

Below: Rev. P. Séguin, Miss Teresa Egan, Henry F. Hall, De Lisle Garneau, G. Harper Hall, Dan P. Gillmor, Mrs. T. Desjardins, L. Marion, Mrs. D. Garneau, Rev. Bro. Crête, Mrs. J. E. Guimont, R. Lespérance, F. J. DeKinder, A. M. Donnelly, P. S. Beauséjour, S.J., J. Edgar Guimont.

THE VILLE MARIE OBSERVATORY AT MONTREAL

By C. A. CHANT

(With Plate VI)

For some years Mr. DeLisle Garneau, an active member of the Royal Astronomical Society of Canada, has been an assiduous observer of the sun and other celestial objects, by means of a 4-inch Lancaster refracting telescope. Recently he obtained from the Montreal Centre of the Society the use of its 6-inch Aitchison refractor, and in order to carry on his work in a convenient manner he built a suitable observatory in the rear of his residence at 4052 Wilson Ave., Notre Dame de Grâce. This has been called Ville Marie Observatory, after the name given to Montreal when founded just three centuries ago.

Constructed of wood, the observatory measures 12 feet to the side and 9 feet high. The central portion of the roof is movable on rails. The objective of the telescope, as has been stated, is 6 inches in diameter; and its focal length is 75 inches. There are five eye-pieces, giving magnifications 110, 150, 220, 300 and 450 times. Observations are possible down to 10 degrees above the horizon. The observatory is supplied with electric light.

On December 7 last—a date which will linger long in American history—a number of Mr. Garneau's personal and astronomical friends assembled to inaugurate the new observatory. Among them was R.P. Séguin, the parish priest of Notre Dame de Grâce, who blessed the observatory in the presence of two clergymen— P.S. Beauséjour, S.J., and Rev. Brother Crête; of officers of the Montreal Centre of the R.A.S.C.—Dan P. Gillmor, K.C., president; G. Harper Hall, vice-president; Henry F. Hall, secretary; Frank J. DeKinder, treasurer and librarian; A. M. Donnelly, member of council; and of other friends—Hector Garneau, historian, J. Edgar Guimont, Edouard Garneau, Roland Lespérance, G. A. Laferrière, L. Marion, Mrs. Julia Garneau, Mrs. Edgar Guimont, Mrs. Thérèse Desjardins and Miss Teresa Egan. Two photographs taken on the occasion of the ceremony are reproduced in Plate V.

After an inspection of the observatory, during which the visitors were given an opportunity to view spots on the sun and also the

planet Venus in full daylight, the party moved to a room in Mr. Garneau's house which had been specially arranged for the meeting. Here several brief addresses were given, the introductory one being by Mr. Garneau, who spoke as follows:

Je désire remercier de tout cœur le Rév. Père Séguin, curé de Notre-Dame de Grâce, qui a bien voulu venir aujourd'hui prêter son concours à l'inauguration de mon Observatoire; merci aussi à tous ceux qui nous honorent de leur présence.

En remontant, par la pensée, le cours des âges, il nous semble entrevoir dans l'antiquité les païens célébrer en grand'pompe, au son des trompettes, l'ouverture d'un nouveau temple à Uranie, Muse du ciel. Aujourd'hui, 7 décembre 1941, veille de l'Immaculée-Conception, un Père dominicain a dédié par la prière, en un geste de bénédiction, cet observatoire à Marie, Reine du Ciel.

Plusieurs facteurs ont concouru au succès de l'entreprise, entre autres la collaboration bienveillante de la ville de Montréal par l'entremise de l'un de ses dignes représentants, le président du Comité exécutif, M. J.-O. Asselin, dont nous regrettons l'absence, la gracieuseté des membres de la Société Royale d'Astronomie du Canada, qui ont mis à notre disposition leur lunette de 6 pouces, grossissant 450 fois; les bons offices de mon ami, M. A.-M. Donnelly, habile constructeur de télescopes, dans la préparation des plans; l'aide précieuse et la contribution de mon dévoué collègue et compagnon de toujours, le distingué fondateur de l'Institut Astronomique et Philosophique du Canada, M. J.-Edgar Guimont.

Jamais nous n'oublierons la nuit idéale passée en sa compagnie sur les bords de la Rivière aux Mille-Iles, en plein champ, à la belle étoile, oui, c'est le cas de le dire, à la belle étoile, car nous avions veillé jusqu'à l'aube non pas seulement à nous griser de la contemplation du ciel étoilé, mais aussi et surtout pour effectuer des observations pratiques. C'est ainsi que nous avions enregistré de nombreuses étoiles filantes, photographié une aurore boréale, fixé des étoiles doubles et reproduit la configuration dse planètes. Malheureusement nous étions exposés à l'humidité, à la rosée, sans protection aucune contre le froid, et nous faisions des projets d'avenir, projets qui se réalisent aujourd'hui.

Nous voudrions profiter de cette circonstance pour rendre hommage à la mémoire de notre tendre mère qui nous encouragea toujours dans la voie que nous voulions suivre; à mon très chere père, présent parmi nous, qui lui aussi nous poussa dans notre vocation; à ma charmante épouse et fidèle collaboratrice, bachelière es arts de l'Université Queens, qui nous ramena à l'Astronomie car nous avions dû l'abandonner temporairement, puisque, comme le disait Képler, c'est une mère qui nourrit peu ses enfants.

Et maintenant vous aimeriez apprendre, sans doute, à quoi servira cer Observatoire, trait d'union entre le ciel et la terre? quel role peut bien remplit sa lunette à côte des télescopes géants du Mont Palomar, du Mont Wilson, de McDonald et de David Dunlap? Oh! nous n'avons pas la hardiesse de prétendre qu'elle puisse même aller à leur cheville, cependant nous aurons du moins la satisfaction d'affirmer qu'elle pourra rendre service. De quelle façon? Lors du rapprochement favorable de la planète Mars en 1939, la Société Astronomique

de France avait décidé la création d'une commission spéciale en vue de recueillir, de centraliser toutes les observations sur notre voisine. Ces membres approuvèrent, comme pouvoir grossissant minimum les lunettes de 5 pouces. Or nous en avons une de 6 pouces. La Commission lunaire, constituée dans le même but, adopta le "4 pouces." La nôtre est de 6. Pour l'observation des comètes et des étoiles variables les appareils de modeste puissance suffisent et là encore nous pouvons coopérer utilement. Ceci m'amène à vous exposer sa sphère d'activité.

Cet observatoire sera consacré tout d'abord à l'étude du soleil, de la lune, des principales planètes, des comètes et des étoiles variables. Il sera consacré aussi à la diffusion de la plus noble, de la plus vieille des sciences, à celle qui "raconte la gloire de Dieu et annonce l'œuvre de ses mains." Il sera ensuite accessible à ceux animés du feu sacré, qui veulent encore approfondir les secrets de la nature; accessible pareillement aux esprits avident de s'instruire, de s'élever dans la connaissance du beau, du grand et du vrai; enfin à ceux-la harassés par les affaires quotidiennes il deviendra un refuge d'où ils pourront, dans le calme des nuits limpides, tendre vers les régions supérieures où palpitent les soleils de l'Univers.

En ces jours horribles de guerre, alors que les hommes que nous qualifierons non de roseaux mais d'insectes pensants s'entre-dechirent en semant la ruine et la désolation, alors qu'ils emploient toute leur intelligence à la fabrication d'instruments dévastateurs; qu'ils braquent au ciel des canons au lieu de télescopes, nous espérons et souhaitons ardemment qu'un jour prochain viendra où ces hommes secoueront une fois pour toutes, le joug infame de la barbarie pour s'unir dans un common idéal: le progrès et le bien-être de l'Humanité.

(English translation at the end of this article)

Then followed an address by Mr. J. Edgar Guimont, a friend and collaborator, as follows:

Vivant au milieu d'une époque troublée, où les œuvres édifiées par l'homme sont vouées à la destruction, ne fait-il pas bon d'être réunis ici pour parler d'œuvres de paix.

L'astronomie, cette science si belle, si vaste, si profonde, qui a pour but la connaissance générale de l'Univers, compte aux Etats-Unis beaucoup d'amis. Malheureusement, en notre pays, l'on ne peut en dire autant des Canadiens-français. Toutefois, quelques-uns réalisant le peu d'intérêt que l'astronomie a suscité chez-nous, ont cru bon de mettre l'épaule à la roue et de donner naissance à un mouvement local, afin de faire mieux aimer l'étude de la voûte étoilée. Citons: Messieurs Nadeau à Québec, en fondant une société et Garneau à Montréal, en construisant un observatoire à ses frais.

Aujourd'hui, je veux rendre hommage à M. Garneau, non pas parce qu'il est mon ami et mon associé, mais par ce que j'ai trouvé en lui l'homme qui mérite vraiment de porter le nom d'astronome amateur. Il en possède du moins tout le caractère. Pour ma part, j'en sais quelque chose, ayant fondé en 1926 une société astronomique à Montréal, (d'une éphémère durée de sept années), j'ai connu la difficulté de trouver chez-nous, le type de véritable astronome. Il m'a fallut attendre seize années, avant d'en trouver un du genre de M. Garneau.

Depuis, je n'ai cessé d'être en contact permanent avec lui, et veuillez me croire, non sans satisfaction et encouragement. Homme affable, réservé, pondéré, humble, travailleur acharné et persevérant, je n'hésite pas à le dire, Mr. Garneau mérite nos éloges et notre encouragement.

En voulez-vous un exemple? L'an dernier, lors du passage de la comète Cunningham, malgré une période de température déplorable, il sut si bien employer à l'observation les courts moments favorables, qu'un astronome de l'observatoire Dunlap, M. Peter Millman, lui rendit hommage devant tous les membres de la Société Royale d'Astronomie du Canada, pour ses nombreuses observations de la comète, que n'avaient pu faire, même les astronomes officiels de l'observatoire de l'Université de Toronto.

Il y a peine dix-huit mois que je connais mon bon ami, et malgré ce peu de temps, j'ai appris à admirer et à aimer ce travailleur consciencieux. Depuis environ un an, il écrit des chroniques astronomiques dans *Le Devoir*, *l'Action Catholique* et *La Patrie*. Non satisfait de cela, il ne voulut pas laisser terminer l'an 1941, sans rendre hommage à la science du ciel, en élevant à gloire d'Uranie ce modeste édifice, où chaque amant du Cosmos, pourra venir mettre l'œil à l'oculaire et scruter la profondeur des cieux, tout en admirant l'œuvre splendide du Createur.

The Rev. Father Séguin, the curé of Notre Dame de Grâce, then offered the following remarks:

Je ne me sens pas très à l'aise au milieu d'un groupe de savants; ma place est plutôt avec les enfants. En tout cas, j'ai été très heureux de me rendre à l'invitation de M. DeLisle Garneau. Quand il m'a demandé de venir ici bénir son observatoire, je l'ai regardé fixement et j'ai vu qu'il avait une bonne figure; je voyais un savant qui voulait travailler pour la gloire de Dieu, sous le patronage de la Reine des Cieux qui a apporté sur terre la véritable étoile: notre Seigneur Jésus-Christ.

Personnellement on m'a bien souvent accusé d'être très souvent dans la lune; on n'avait pas tort. Mais j'espère ne pas outrepasser mes droits en priant M. Garneau de m'octroyer la permission de venir considérer la lune et les étoiles de son observatoire et me faire renseigner sur ces merveilles. Et je dirai aux enfants, en leur commentant les Saintes Ecritures, que les étoiles chantent, elles aussi, la gloire de Dieu.

The last address was by Mr. Dan P. Gillmor, K.C., president of the Montreal Centre of the Royal Astronomical Society of Canada, who said:

It is very refreshing to meet people who manage to keep their feet on the ground while looking at the stars. They are not stampeded by all the "isms" of the present era and stick to something grand.

As I said, it is very refreshing indeed to find a young man who turns his attention theoretically and practically to the science of astronomy. I feel some good is to come to the community from his observations. This observatory will

enable children, not only skilled ones like yourselves, but also like myself, who know very little, to read the message of God in the stars.

I congratulate you and hope that you are not going to stop now, and wish you a successful career.

TRANSLATION OF MR. GARNEAU'S ADDRESS

I wish to thank most heartily Reverend Father Séguin, Parish Priest of Notre Dame de Grâce, who has graciously condescended to come to-day to lend his assistance at the inauguration of my observatory. I wish to thank also all those who are honoring us with their presence on this occasion.

Glancing back, in one's mind, on the course of centuries, we recall how in ancient times the pagans were wont to celebrate with pomp, at the sound of trumpets, the opening of a new Temple to Urania, Muse of the sky. To-day, on the 7th of December, 1941, the eve of the Feast of the Immaculate Conception, a Dominican Father has dedicated by prayer and benediction this observatory to Mary, Queen of Heaven.

Many factors have concurred to make this enterprise a success; amongst them the kindly assistance of the City of Montreal through the medium of one of its worthy representatives, the Chairman of the Executive Committee, Mr. J. O. Asselin, whose absence from this meeting we regret; the graciousness of the members of the Royal Astronomical Society of Canada, who have placed at our disposal their 6-inch telescope, magnifying 450 times; the good counsels of my friend, Mr. A. M. Donnelly, skilful telescope maker, in the drawing of the plans; the precious aid and contribution of my devoted colleague and trusted companion, the distinguished founder of the Astronomical and Philosophical Institute of Canada, Mr. J. Edgar Guimont. Never shall we forget that wonderful night spent in his company on the banks of the Thousand Islands River in a field under the stars, for we had stayed up until dawn, not only to rejoice in the contemplation of the starry sky, but also, and above all, to make practical observations. So it happened that we had recorded numerous shooting stars, we had photographed an aurora borealis, jotted down double stars and reproduced the configuration of planets. Unfortunately we were exposed to humidity, to dew, without any protection against the cold, and so we began making plans for the future, plans that have come true to-day.

On this occasion I wish to pay tribute to the memory of my dear mother, who always encouraged me in the career I had chosen. I wish also to express my gratitude to my dear father, present amongst us, who helped me realize my vocation; to my charming wife and faithful collaborator, a graduate of Queen's University, who re-awakened my enthusiasm in astronomy, for we had to forsake it temporarily because, as Kepler was wont to say, "She is a mother who nourishes her children scantily."

And now most assuredly you would like to know the usefulness of this observatory, the link between the heavens and the earth. What part can its telescope play when compared with the giant telescopes of Mount Palomar, of Mount Wilson, of McDonald and of David Dunlap? Oh, we haven't got the audacity to pretend that it will reach even to the knees of those giants. Yet we shall have the satisfaction of stating that it will render service. In what way? At the time of the favourable opposition of the planet Mars in 1939, the Astronomical Society of France had decided to create a special Commission to collect, to centralize all the observations on our neighbour. This Commission approved as the minimum a 5-inch telescope; now ours is a 6-inch one. The Lunar Commission, constituted for the same purpose, adopted the 4-inch. Ours is a 6-inch one. For the observation of comets and variable stars the instruments of low power suffice, so there again we can coöperate usefully.

This brings me now to discuss with you its sphere of action. This observatory will be used for studying the sun, the moon, and the principal planets, the comets and the variable stars. It will also be used for the diffusion of the noblest, of the oldest of the sciences, that science which "declares the glory of God and shows forth the works of His hands." It will also be accessible to those who wish to investigate the secrets of nature; accessible also to minds eager to learn, to acquire, the meaning of beauty, grandeur and truth; lastly, to those weary of their daily round it will become a refuge whence in the calm of the clear night they can reach the lofty regions where the suns of the Universe sparkle.

In these horrible days of war, at this time, when men, whom we shall call not reeds but thinking insects, are destroying themselves while sowing ruin and desolation; at this time, when they use the best of their intelligence to construct weapons of destruction; when they point guns instead of telescopes towards the sky, we dare to hope, and ardently wish, that in the very near future, these men will shake off once and for all the infamous yoke of barbarism, and in doing so, will unite in promoting a common ideal—the progress and the well-being of Humanity.

DAVID DUNLAP OBSERVATORY

OUTLINE OF WORK JULY 1940—JULY 1941

By R. K. Young

General Program

SINCE the opening of the observatory we have been engaged in the determination of the radial velocities of the stars not previously observed and have for the most part focussed our attention on those stars in and near the Kapteyn Selected Areas. The first program included all those stars in areas four degrees square down to declination + 15° and limiting magnitude 7.59. This list included 500 stars and was completed and published in 1939. As mentioned in our last report we have undertaken an extension of this program and have enlarged the areas to six degrees square. There are 404 additional stars in the enlarged areas and we aim to secure four or more plates of each star. About 350 plates remain to be taken to complete this program. In the region of the sky from 19-24-9 hours of right ascension the 6 × 6 degrees program is practically finished and we have enlarged the areas to 8 × 8 degrees. There are 129 additional stars in these enlarged areas and about 310 plates will be needed to complete the observation of them. In addition we are observing a list of 189 bright stars, scattered over the northern hemisphere, for which no velocities are published.

During the year 959 plates were taken and the measurement of the plates has been fairly well kept up, considering the curtailment of our staff. Plates were measured as follows: by Mr. Bunker, 360; by Mr. Buscombe, 451; by Miss R. J. Northcott, 181; about 200 plates remain to be measured.

Special Researches

During the year the observatory has been very short of observers and it has required nearly all the time of the remaining staff to keep the main program in operation. Consequently special researches have suffered somewhat.

Dr. F. S. Hogg has continued to work on an instrument for aerial navigation. Three improved models have been constructed in

the observatory workshops and are at present undergoing tests by the Air Force.

Good progress has been made on the construction of a vacuum tank for aluminizing the 74-inch mirror.†

Dr. Helen S. Hogg, research associate, has been on leave of absence for the year to be chairman of the department of astronomy at Mount Holyoke College, South Hadley, Massachusetts. During vacations she has continued research on globular clusters, and 143 plates have been secured at the Newtonian focus for this purpose. A paper on the variables in the Hercules cluster should be ready shortly as a D.D.O. publication and it is expected that periods in one or two other clusters will be published during the coming year.

Miss R. J. Northcott has investigated the spectroscopic binary HD 93075 whose variability was discovered by Dr. F. S. Hogg at this observatory. Miss Northcott derives a preliminary period of 1.8052 days. She also completed the orbit of HD 22124, which appears as *D.D.O. Publication* No. 8.

Mr. A. F. Bunker has measured line intensities in all the plates taken with the one-prism instrument 25-inch camera with a view to absolute magnitude determination. Completion of this work will have to be left in abeyance till more plates are available as the limited material does not suffice to investigate systematic errors sufficiently.

Mr. G. H. Tidy,* who left the observatory at the beginning of the year to join the Canadian Navy, completed the orbit of the spectroscopic binary HD 1826, which appears as *D.D.O. Publication* No. 6.

Dr. J. F. Heard left the observatory in November to join the Royal Canadian Air Force. He completed the orbit of HD 9312 (*D.D.O. Publication* No. 7) and investigated the velocity variations of HD 142926 (*D.D.O. Publication* No. 9.)

Dr. P. M. Millman left the observatory in February, 1941—also to join the Royal Canadian Air Force. Before his going he completed two publications: General Instructions for Meteor Observing (*D.D.O. Communications* No. 6) and The Perseid Meteor Shower,

†Described in the January issue of this JOURNAL.

*See obituary notice, page 129.—Editor.

1940 (*D.D.O. Communications* No. 7). A fuller report on these activities will be given on Dr. Millman's return.

The following publications were issued by the Observatory during the year:

Bunker, A. F., The Spectra of Peculiar Strontium Stars, *Publ. D.D.O.*, Vol. 1, No. 10.

Heard, J. F., The Orbit of the Spectroscopic Binary HD 9312, *Publ. D.D.O.*, Vol. 1, No 7.

Heard, J. F., The Spectrum and the Velocity Variation of HD 142926, *Publ. D.D.O.*, Vol. 1, No. 9.

Millman, P. M., General Instructions for Meteor Observing, *Comm. D.D.O.*, No. 6.

Millman, P. M., The Perseid Meteor Shower, 1940, *Comm. D.D.O.*, No. 7.

Northcott, Ruth J., The Orbit of the Spectroscopic Binary HD 22124, *Publ. D.D.O.*, Vol. 1, No. 8.

Tidy, G. H., The Orbit of the Spectroscopic Binary HD 1826, *Publ. D.D.O.*, Vol. 1, No. 6.

ON THE P CYGNI CHARACTERISTICS OF H.D. 190073 AND THE DIMENSIONS OF ITS EMITTING AND ABSORBING SHELLS

By C. S. Beals

I. Introduction

THE unusual character of the spectrum H.D. 190073 $\alpha(1900)$ $19^h\ 58^m.1$, $\delta(1900)$ 5° 28′, Mag. 7.9 A0ep.) was discovered by Merrill.[1] He pointed out that this was the only stellar spectrum so far observed, excepting the Novae, with bright sodium lines. He also called attention to the complex character of the *H* and *K* lines of Ca II which consisted of emission bordered on the violet by double absorption lines. He further referred to the appearance, in emission, of lines due to ionized metals and characterized the hydrogen emission lines as typical of class Be.

The star was placed on the Victoria observing programme because the nature of the *H* and *K* lines suggested a relationship with the P Cygni stars. Intercomparison of Victoria plates and comparison with Merrill's published data make it clear that the star is a spectrum variable. The variability appears to affect mainly the hydrogen lines which change from a typical Be structure to the unsymmetrical forms indicated in Fig. 1. The Be phase is illustrated by the profile of Hβ in Fig. 2 derived from a tracing kindly supplied by Merrill. The lines of Ca II and other elements also probably undergo small variations but these variations have so far been found to be much less marked than those of the hydrogen lines. It has not yet been determined whether the variation is of an irregular or a periodic nature.

The first part of the present discussion deals with a particular phase of the spectrum represented by the hydrogen lines of Fig. 1. The latter part of the paper is concerned with the peculiar Ca II profiles of Fig. 5.

The particular phase of the hydrogen line profiles shown in Fig. 1 appeared in its full development on only two of the Victoria plates, the first of which covers the ordinary photographic region

[1] *Astroph. Jour.*, vol. 77, p. 51, 1933.

from λ3800 to λ5000 while the second covers the visual region from λ5800 to λ6900. The first plate covering the ordinary region was secured on October 29, 1937, while the visual plate was taken a year later, on October 31, 1938. It is, of course, impossible to say how closely the phases of the two plates correspond but in the discussion which follows it will be assumed that they are closely similar.

The profiles of the hydrogen lines shown in Fig. 1 and of the Ca II lines shown in Fig. 5 have been determined in the usual way from plates calibrated with a rapidly rotating step-sector. Unfortunately the faintness of the star has necessitated the use of small dispersion (51A. per mm. at Hγ) so that the narrower central portions of the line are largely influenced by the slit pattern. As a consequence subsequent discussions of the interpretations of these profiles must necessarily refer mainly to their general character and any attempt at very precise fitting of the shapes of observed and computed curves is without significance.

II. The Hydrogen Line Profiles

A complete interpretation of the spectrum of this star must take account not only of the forms of the hydrogen lines and their variability but also of the peculiar character of the other lines notably those of Ca II. As a first step in such an interpretation we consider the hydrogen line profiles of Fig. 1. These profiles may briefly be described as consisting of three parts, as follows:

1. A broad winged absorption line about 65 A. in width.

2. A much narrower P Cygni profile (emission with absorption on its violet edge) centrally superposed on the broad absorption line.

3. A structural feature consisting of a dip in the emission line somewhat to the violet of its centre.

The Broad Winged Hydrogen Lines. Taking first the broad underlying absorption line we may note that for Hζ the broad line appears to be practically free from the influence of the narrower emission and absorption features which appear in earlier members of the series. A few trials led to the following formula for the intensity r at a displacement u from the line centre assumed to be at zero velocity, u being measured in velocity units (km./sec.),

$$1-r=(1-r_0)e^{-h^2u^2} \quad . \quad . \quad . \quad (1)$$

$1-r$ is the fraction of the continuous spectrum absorbed at a given displacement, r_0 is the intensity at the line centre expressed

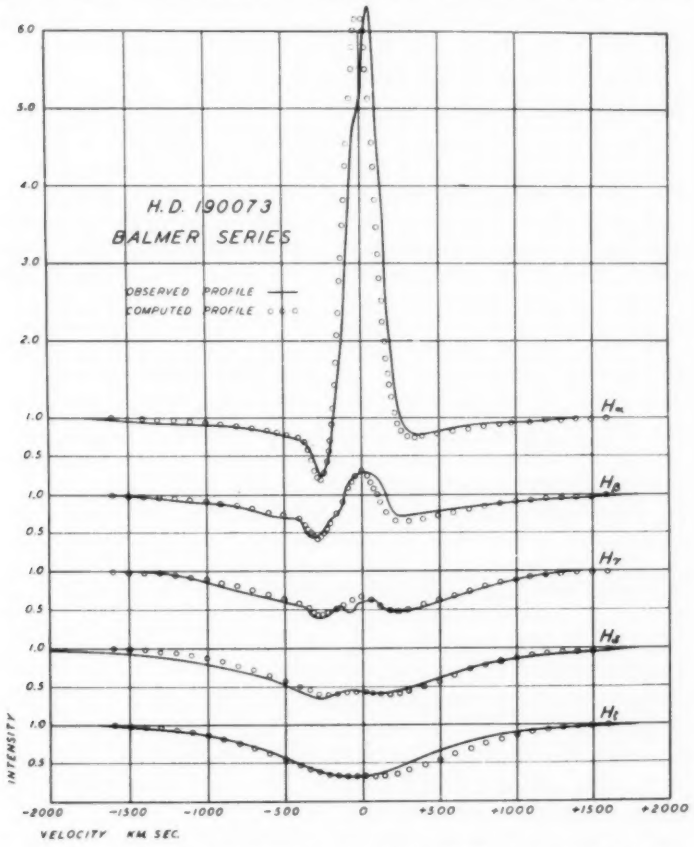


Fig. 1.—Profiles of Hydrogen lines, H.D. 190073 in its P *Cygni* phase. Full line—Observed Profile. Circles—Computed Profile.

as a fraction of the continuous spectrum, and $h^2=1.61\times10^{-6}$.

Assuming that the other lines have the same form as Hζ we

may, by fitting the above formula to the wings, derive central intensities for earlier members of the series. Actual values follow in Table I.

TABLE 1

Line	r_0 (H.D. 190073)	r_0 (other late B stars)
Hα	0.70	0.70
Hβ	0.60	0.60
Hγ	0.45	0.50
Hδ	0.35	0.46
Hϵ	0.32	0.46
Hζ	0.30	0.46

The decrease in the central intensities of the Balmer lines with series number appears to be a normal feature of early type spectra. In Williams's[2] extensive observations, comprising over 70 stars

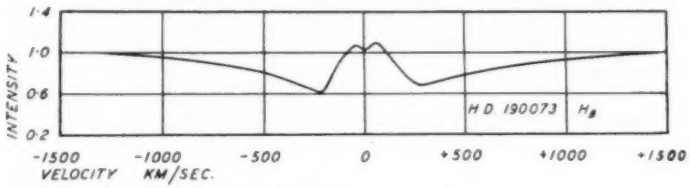


Fig. 2.—Profile of *H*β, H.D. 190073, in its Be phase. (*From a tracing kindly supplied by P. W. Merrill.*)

of types B and A, the average central intensities decrease from Hβ to Hδ and remain approximately stationary for such higher series members as have been observed. Williams's results were confined to the ordinary photographic region but the work of Gunther[3] has indicated that in general the absorption at Hα is about twenty-five per cent weaker than at Hβ. In the last column of Table I are given average values of Balmer central intensities for nine late B-type stars observed by Williams. The value given for Hα is an estimate based on Gunther's measures referred to above. The run of intensities in the series is sufficiently similar to that in H.D. 190073 to suggest that the broad winged lines of this star are produced in a reversing layer not greatly different from that

[2] *Astroph. Jour.*, vol. 83, p. 1, 1936.
[3] *Zeitschrift f. Astroph.*, vol. 7, p. 106, 1933.

of many other early type objects which do not show emission lines. In the remainder of the discussion the correctness of this conclusion will be taken for granted and it will be further assumed that the depth of the reversing layer is negligible compared with the stellar diameter.

The P Cygni Components. We next investigate the effect of postulating the existence, outside the reversing layer, of an extensive shell of outward moving atoms. While this aspect of the subject is not discussed in detail it is generally assumed, for lack of any obvious alternative, that the ejection of atoms is due to radiation pressure. If the shell is large relative to the star and transparent except in the neighbourhood of the spectral lines we may assume that the intensity of the absorption line will follow the law

$$I = I_c \, 10^{-\tau_v} \qquad . \; . \; . \quad (2)$$

Where τ_v is the optical thickness at the particular wave-length, or velocity displacement, involved and I_c is the intensity of the continuous spectrum at the same wave-length.

The over-all distribution of velocities in the absorbing column will then determine the form of the line. There appears to be no *a priori* means of predicting the nature of this distribution so we will assume that it has the form of a Gaussian error curve* with the most probable velocity represented by v_a.

Since the optical thickness is directly proportional to the number of absorbing atoms moving with velocity v then the value of τ_v will be given by equation (3)

$$\tau_v = \tau_a \, e^{-j^2(v_a - v)^2}, \qquad . \; . \; . \quad (3)$$

where τ_a is the optical depth in the centre of the displaced absorption line corresponding to velocity v_a and j is an empirical constant. The intensity in the line will then be completely represented by the expression

$$I = I_c \, 10^{-\tau_a e^{-j^2(v_a - v)^2}} \qquad . \; . \; . \quad (4)$$

*This assumption is a numerical device to take account of the observed shape of the line. It does not imply that the velocities at any given radius have a Gaussian distribution. The distortion produced by the spectrograph has been of necessity disregarded although it obviously has an important influence on the line profile.

Apart from the influence of neighbouring emission, v_a is given directly by the radial velocity of the displaced absorption line. I_c corresponds to the r of equation (1). τ_a may be computed from the observed depth of the displaced line making use of (2) and (1) while the constant j^2 must be determined by trial on the basis of the width of the line. Modifications in the value of τ_a and v_a are necessary when the effect of the emission line is later taken into account.

Turning next to the emission line we shall assume for the present that it also has an exponential form as in equation (5),

$$I = I_{max.} e^{-k^2 v^2} \quad . \quad . \quad . \quad (5)$$

where $I_{max.}$, the central intensity, is determined directly from observation, the constant k^2 is found by trial and the centre of the line corresponds to zero velocity.

The Combined Profile. Beginning with the broad underlying line of equation (1) we compute the modification of its form by the process represented by equation (4). The effect of the emission line (equation (5)) is then taken into account by the simple process of summation of ordinates.

A test of the general validity of this line of reasoning may be made by computing the form of Hα as outlined above and then making use of the f values for the Balmer series and an assumed value of the Balmer decrement to compute the forms of Hβ, Hγ, Hδ, and Hζ.*

The f values due to Sigiura[4] are given in Table 2. This table also contains the value of τ_a. A few trials using equations (1), (4)

TABLE 2

Line	f Value	τ_a
Hα	0.6408	1.0
Hβ	0.1193	0.186
Hγ	0.0447	0.0698
Hδ	0.0221	0.0344
Hϵ	0.0127	0.0198
Hζ	0.0080	0.0125

[4] *Jour. de Physique et de Radium*, vol. 8, p. 113, 1927; *Scientific Papers, Jap. Inst.*, vol. 11, p. 56, 1929.

*Hϵ is obscured by Caπ, *H*.

and (5) led to a value of $\tau_a = 1$ for Hα and for the remaining lines τ_a has been taken to be proportional to the f value.

The Balmer decrement for the emission lines has been computed on the basis of an interesting relationship pointed out by O. C. Wilson[5] in connection with studies of RS (Nova) Ophiuchi. According to this relation, if the logarithms of the intensities of successive lines in the Balmer series are plotted against $N^{1/3}$ where N is the series number of the line (1 for Hα, 2 for Hβ, etc.) then the resulting graph is close to a straight line, regardless of whether the slope is large or small. While the physical basis underlying this relation is obscure its use in the present instance is justified by the fact that it accurately describes the behaviour of most stellar and nebular hydrogen emission lines.

Using this procedure, the observed central intensities of Hα and Hβ have been used to fix the slope of the straight line and the remaining intensities have been read directly from the same graph. The values of the central intensities are given in the first column of Table 3. The second column contains values of E_λ (the intensity distribution in the continuous spectrum) for the corresponding wave-lengths. Since the observed values of intensity are measured relative to the continuous spectrum it is necessary to divide the values of the Balmer decrement by E_λ in order to reduce them to a comparable scale. The values of E_λ in the table correspond to a colour temperature of 10,000° K., the ordinarily accepted value for an early A-type star. While recent studies of colour temperature have tended to increase this value, the matter is still in a state of considerable uncertainty and the calculations of this paper

TABLE 3

Line	Balmer Decrement (Central Intensity)	Relative E_λ	Intensity Relative to Cont. Spectrum
Hα	5.60	1.00	5.60
Hβ	1.38	1.95	0.71
Hγ	0.52	2.37	0.22
Hδ	0.24	2.58	0.093
Hϵ	0.13	2.70	0.048
Hζ	0.07	2.76	0.025

[5] *Astroph. Jour.*, vol. 80, p. 344, 1934.

would not be seriously affected by a change in the scale of the order of 2,000° or 3,000° K.

Fitting the formulae (1), (4) and (5) to Hα in the manner outlined above we find for the two constants j^2 and k^2

$$j^2 = 2.30 \times 10^{-4},$$
$$k^2 = 5.75 \times 10^{-5}.$$

The values of τ_a for successive members of the Balmer series have already been given in Table 2. Similarly the observed central intensities relative to the continuous spectrum, of the emission lines at Hα and Hβ were 5.60 and 0.71 and the values for the remaining lines were found from the Balmer decrement and are given in Table 3. The mean velocity of the displaced absorption lines in the ordinary region is -280 km./sec. That for Hα is -244 km./sec. and the emission line appears to be displaced to the red relative to the other lines. In view of the known variability of the star's spectrum, and the fact that the spectrum of the red region was taken at a different date, the value of v_a for Hα was taken as -240 km./sec. as compared with -280 km./sec. for the remaining lines.

Comparison With Observation. On this basis the forms of the lines Hα, Hβ, Hδ, and Hζ were computed and the agreement with observed profiles is shown in Fig. 1. In spite of obvious discrepancies, of which the asymmetrical shape of Hα is the most striking, the fit on the whole is reasonably good. As has already been mentioned, any significance which may attach to a comparison of the observed and computed profiles must refer to their general character since the influence of the spectrograph on the line character cannot be completely eliminated. However, it would appear that the quantitative agreement shown by the figure would hardly be possible unless the exponential law of absorption assumed for the displaced absorption line were approximately valid. The existence of such a law of absorption is in accord with the general picture of a stratified atmosphere presented on page 149, with the displaced absorption line arising in a diffuse layer of outward moving atoms situated at a height above the regular reversing layer which is large relative to the stellar radius.

Self-Reversal of Emission Lines. One other feature of the hydrogen line profiles remains to be mentioned. This feature

consists of a depression in the emission component of Hγ somewhat to the violet of the line centre and a similar though less well defined depression in Hα which apparently is responsible for the marked asymmetry of the line. Its non-appearance in the case of Hβ may be due to observational difficulties. If this feature be regarded as absorption then it is clear that it is an absorption line of considerable strength which cannot be disregarded in any attempt to interpret the hydrogen line profiles.

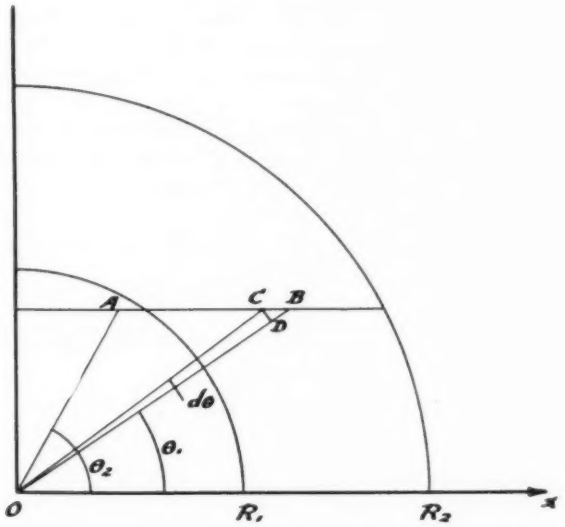


Fig. 3.—Geometrical relations involved in discussion of self-reversal.

The most immediately obvious explanation of this feature is that it is a consequence of self-reversal within the envelope of gases surrounding the star. The effect of self-reversal under somewhat similar circumstances has been discussed by Gerasimovič,[6] in connection with the Wolf-Rayet stars and Novae. He pointed out the difficulties of a complete mathematical treatment and concluded that, for these stars, such modification of the line profile as

[6] *Zeitschrift f. Astroph.*, vol. 7, p. 335, 1933.

might occur would have its maximum effect on the wings of the line and would not take the form of a depression near the line centre.

In the following discussion the mathematical difficulties have been largely avoided by the use of certain simplifying assumptions and an attempt has been made to arrive at some conclusion as to the conditions under which observable self-reversal may occur by an elementary consideration of general physical principles. The initial simplifying assumption is that all the absorption takes place in a layer outside the part of the envelope where the monochromatic emission has its origin. This resembles the old assumption of a separate photosphere and reversing layer and suffers from similar defects but it is hoped that the existence of these defects will not entirely invalidate the conclusions.

Consider an envelope of outward moving gases surrounding a star where all the emission takes place within a radius R_1, while absorption occurs in an outer shell of thickness R_2-R_1 as in Fig. 3. If the observer's line of sight is defined by OX then for atoms situated at a point (r, θ) with a velocity of ejection v_r the component of this velocity in the x-direction will be

$$v_x = v_r \cos\theta \qquad . \; . \; . \quad (6)$$

and for any two points A and B situated on a line parallel to OX the difference in velocity will be

$$\Delta v_x = v_{r_1} \cos\theta_1 - v_{r_2} \cos\theta_2 \qquad . \; . \; . \quad (7)$$

From this it is clear that if Δv_x is greater than w, the natural width of the line due to thermal or turbulent motions and radiation damping the atoms at B will be transparent to radiation from A. While it would, of course, be necessary to solve an equation of transfer to determine the modification which the shell would produce on the radiation from beneath, a general idea of what is likely to take place may be gained by studying the variation of the quantity dv_x/dx with θ. Since for any given optical path Δx, the value of Δv_x in equation (7) must depend upon the value of dv_x/dx in that vicinity, the opacity will vary inversely with dv_x/dx, maximum absorption taking place when $dv_x/dx = 0$. We may derive an expression for this quantity as follows.

Since the value of v_x varies with both θ and r we may set

$$v_x = f(\theta, r)$$

then by differentiation

$$\frac{dv_x}{dx} = \frac{\partial v_x}{\partial \theta}\frac{d\theta}{dx} + \frac{\partial v_x}{\partial r}\frac{dr}{dx}, \quad \ldots \quad (8)$$

from (6) by partial differentiation with respect to θ and r,

$$\frac{\partial v_x}{\partial \theta} = -v_r \sin\theta \quad \ldots \quad (9)$$

and

$$\frac{\partial v_x}{\partial r} = \frac{dv_r}{dr}\cos\theta \quad \ldots \quad (10)$$

From Fig. 3 in the small triangle BCD

$$r d\theta = -dx \sin\theta,$$

and

$$\frac{d\theta}{dx} = -\frac{\sin\theta}{r}, \quad \ldots \quad (11)$$

and

$$\frac{dr}{dx} = \cos\theta. \quad \ldots \quad (12)$$

Thus combining (9), (10), (11), and (12)

$$\frac{dv_x}{dx} = \frac{v_r}{r}\sin^2\theta + \frac{dv_r}{dr}\cos^2\theta \quad \ldots \quad (13)$$

We now consider three cases of (13)

$$dv_r/dr = 0 \quad \ldots \quad (a)$$

$$dv_r/dr > 0 \quad \ldots \quad (b)$$

$$dv_r/dr < 0 \quad \ldots \quad (c)$$

For (a) the value of dv_x/dx has its minimum value for $\theta = 0$, corresponding to the violet wing of the emission line, increasing to a maximum for $\theta = \pi/2$, corresponding to the line centre. It will accordingly be expected that self-reversal will have its maximum effect near the violet wing of the line with no tendency for an absorption minimum near the line centre.

For case (b) dv_x/dx will not approach zero for any value of θ and a sharp minimum for large values of θ is only possible if $dv_r/dr >> v_r/r$. The conditions necessary for a minimum are illustrated in Fig. 4 where dv_x/dx is plotted against θ, the different curves corresponding to different values of $\dfrac{dv_r}{dr}\Big/\dfrac{v_r}{r}$. If $r*$ is the radius of the star then the average value of dv_r/dr over the distance

$r-r*$ is $v_r/r-r*$. It would thus hardly be expected at such distances from the star as self-reversal would likely occur (say several stellar radii) that dv_r/dr would be of a different order of magnitude from v_r/r. It may further be pointed out that, on the basis of the model of Fig. 3, θ will not approach $\pi/2$ very closely, so that while dv_x/dx may, under certain circumstances approach a minimum for large values of θ, the minimum value will still be relatively large and conditions will be unfavourable for strong self-reversal. It

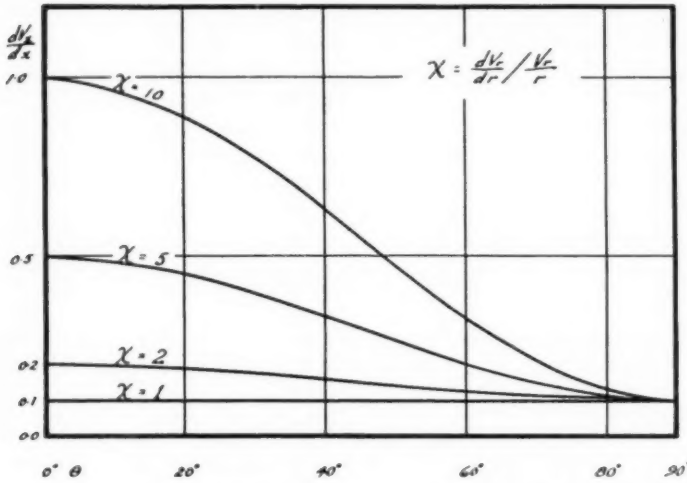


Fig. 4.—Illustration of conditions necessary for a maximum value of dv_x/dx case (*b*).

should be specially noted that for *very large* values of Δx the integral

$$\Delta v_x = \int_{x_1}^{x_2} \frac{dv_x}{dx} dx >> w \qquad . \; . \; . \quad (14)$$

where w is the natural width of the line, so that cases (*a*) and (*b*) cannot under such circumstances result in observable absorption.

Case (*c*). Here the two parts of the right hand member of equation (7) are of opposite sign and the value of dv_x/dx will reach zero for some value of θ depending on the numerical values of the various quantities. Except for very thin shells the question of

whether or not an absorption minimum would make its appearance would have to be determined by integration, but case (*c*) evidently offers the most favourable circumstances for the formation of such a line.

One of the most interesting cases of (*c*) and the one which is probably of greatest importance in connection with the observations of this paper is that where the radius of the emitting part of the envelope is small relative to that of the layer producing self-reversal. Under such circumstances only small values of θ are involved and, to a first approximation

$$dv_x/dx = dv_r/dr \quad . \quad . \quad . \quad (15)$$

A sharp line will be produced when dv_r/dr approaches zero, i.e., when the atom reaches a constant velocity either due to the balancing of accelerating and retarding forces or because it has reached such a great distance from the star that both the retardation produced by gravitation and the outward accelerating force are inappreciable. Of special interest is the limiting case where both $dv_r/dr = 0$ and $v_r = 0$.

Case (*c*) evidently requires that the atom receive a large initial impulse resulting in a maximum outward velocity before reaching the layer where self-reversal occurs. The atom then suffers a retardation of its velocity by the gravitational field of the star. For a shell in dynamical equilibrium such a retardation would not prevent the escape of the atom from the star although the escape would take place with diminished velocity.

It would appear that the structural features observed in the hydrogen emission line profiles of H.D. 190073 are most readily explicable in terms of case (*c*). Such a conclusion, if its validity could be fully demonstrated, would considerably clarify our knowledge of the behaviour of atoms ejected from the surface of this star and of other stars which show similar features. The matter is discussed further on page *xx* in connection with the profiles of the *H* and *K* lines of Ca II and evidence is presented which strongly supports the above conclusions regarding the general character of the motions of atoms ejected from the surface of H.D. 190073.

(To be concluded)

REWARD

If you can grind two discs of glass together
With steady, even, measured stroke and slow;
If you can carry on in spite of weather,
Through summer heat or winter cold and snow;
If you can persevere when all pals flout you
But make allowance for their flouting too;
Nor yet get mad while people round about you
Are laughing at the funny things you do;

If you can read each evanescent shading
The moving knife-edge throws before your eyes
And learn from them your mirror's perfect grading
Will ease your work when you parabolize;
Yet not give up nor yet become desponding
Nor chuck the mirror far across the hedge
When tests give you the shadows corresponding
To deep hyperbola or turned down edge;

If during all the hours it takes to figure
You do not lose the mirror-maker's touch,
Nor when it passes all its tests with rigour
You do not get elated over-much;
Why then, when set within its goodly mounting
And you look back upon a job well done,
Yours are the skies, their glories past all counting,
For you'll have made a telescope, my son.

Victoria, 1942. H. B. B.

THE DEPRESSION OF LUNAR CRATERS

By THOMAS L. MACDONALD

IT was a rather unusual surprise to find in this JOURNAL for November 1941, just before a minor note of my own, a much more important contribution from New Zealand based on some work which I published ten years ago. It was even more of a coincidence that the JOURNAL reached me on the day of Mr. Winston Churchill's historic broadcast from the Houses of Parliament in Ottawa. But that is sufficient for personal comment. The work which I did on lunar altitudes and depressions was in fact extremely disappointing. To read some popular books on the moon, one would think that it was as well known, at least, as Abyssinia. In reality the contradictions and disagreements between the published figures are so great that it was difficult to get any results which would bear statistical discussion at all. There are several reasons for this. The main series of observations of the heights of lunar mountains are still those made by Beer and Mädler before 1850 and by Schmidt not long after. At that time the positions of the craters on the moon were also very badly measured. These observers used a method due to Olbers, in which one measured not only the length of the shadow, but also the distance of the peak both from the terminator and from the north or south limb, two long ranges in which error was very easy. In particular you have only to glance at some photographs of the moon to see that the terminator is often impossible of definition. In the present century several methods have been worked out, which make use of the fact that the positions of most craters are now sufficiently well measured for the purpose in view. None of these methods has ever been used in a really long series of new measures which would give data for an effective study of the true shape of lunar craters. Hevler made 219 measures of eight regions; a very interesting study of the shape of Theophilus was published from the Observatory of the University of Michigan, using the McMath-Hulbert motion picture negatives; and the latter paper has served among other things to bring out an unsuspected source of error in all the previous theories. But these

papers stand in isolation. To take one of the very best determined of all lunar altitudes, we find for Theophilus ϵ:

Mädler	4380 metres
Schmidt	4125
Hevler	4820
Michigan Obs.	4880

As the agreement of the two modern observers is reassuring, we see that Schmidt was something like half a mile wrong. Where there are only two or three discordant measures by old observers, one can only expect an even larger probable error.

The next snag is one which R. A. McIntosh points out at the top of p. 365 of the November issue. Fracastorius is shown on the smallest maps of the moon. One glance at a photograph will show that the wall has been completely destroyed on one side and the interior "flooded" from the dark region on the north (below in the telescope of course). In this case the depression of the interior should on the face of it be zero. It would be very difficult to draw a line and determine at the present stage just which objects should be excluded on this account: and yet it is bound to invalidate general results to some extent.

There are other objects like Wargentin, in which, for some reason which we just do not know, the whole or almost the whole of the interior has been filled up, apparently even overflowing the lower part of the wall. McIntosh asks why the explosion should *invariably* leave behind it only sufficient material in the walls to fill the depression formed. It is true that this is approximated to by the greater number of lunar formations: but it is *not* invariably true. The late Walter Goodacre, one of the most reliable of observers, examined a number of other formations of the Wargentin type. At least one attempt has been made to classify lunar craters in an interesting way: by using the ratio of the walls to the depression. For a normal crater, the material in the walls does about equal the space left in the depression: in that case the ratio is 1:1 or unity. For a pit with no visible walls, it is 0:1 or zero. For an object like Wargentin, with no noticeable depression it is 1:0 or infinity. Here

again, the difficulty is that the material available does not allow us to go very far along this path: if we could, the results might be decisive as to the origin of lunar craters.

It is therefore all the more remarkable that McIntosh has been able to establish a reasonable correlation between diameter and depression. I had hesitated to give any weight to such a correlation. I was impressed by the great relative depth of small objects which appeared "undamaged", objects like Diophantus, Theaetetus, and Peirce. But there is certainly some relationship.

Now what effect will such a relationship have on theories of the origin of lunar craters? McIntosh feels, I think, that it may be fatal to the volcanic theory. If he is thinking of the sort of volcanic theory which is well known from the old-time advocacy of Nasmyth and Carpenter, it is probably true. But no one can now defend a form of volcanic theory which is in defiance of the laws of motion. In that theory, the walls are formed by material ejected from a volcanic vent. No one could ever have shown reason why such ejectamenta should have a lateral velocity which would carry them in a fountain-like curve over many miles of open country and deposit them in nearly circular walls.

The sort of volcanic theory which one must contemplate now is very different. The structure of the moon is not a "contraction geology" such as we find on our own world: it has no wrinkles. It seems clear that it is an "expansion" or at least "exudation" geology. There are various forms of the theory which it would be tedious to detail. In general, the basis is that the crust became weakened by heat expansion from beneath: perhaps after the formation of the crust the remaining interior heat was banked up, as one might say; perhaps, according to another view, radioactivity played a part; one can't know. In any case, under the pressure of expansion from below a break took place and the crust, perhaps pressed outwards at the last in a sort of dome, was replaced by a pool of cooling molten substance. It solidified first where it overflowed the edges of the still stable crust and as the remainder cooled it would contract below the old level: the depression would then exactly balance the upthrown material left round the edges. And,

the point of the present argument, the greater the convulsion, the greater the heating responsible, the higher the molten pool, and the greater the depression. What McIntosh finds would exactly fit in with such a theory. I found it quite absurdly difficult in the tests I made at various times, to get anything which would really discriminate between a volcanic and a meteoric theory. If the effect of the present note is negative and extends the depression from the craters on the moon to the reader, I should wish to stop with a constructive suggestion.

For some reason lunar studies have never reveived much attention in the New World. Neither in Canada nor the United States do drawings and measures of objects on the moon take up the space of astronomical journals. But if we are to decide the questions raised by this correspondence, we shall only do it in the long run by more and better observational work. There are too many places where lunar observation is difficult or impossible at present. If there are any who read this who would take up the work, I should most willingly extend to them the co-operation of the Lunar Section of the B.A.A., of which I have for the present the honour to be director.

1 Graingerville North,
Newcastle upon Tyne, England
1941 December 30

REVIEW OF PUBLICATIONS

Troubadour of the Stars, by Olaf Saile. Translated from the German by James A. Galston. Veritas Press (Oskar Piest), pp. 344, 1940.

The Romantic Life of Johannes Kepler, the secondary title of this book, indicates the scope of the contents. Johannes Kepler is known to all astronomers as the man who, in the early years of the seventeenth century, first formulated the laws which the planets obey in describing their courses around the sun. The discovery of the three famous Keplerian laws of planetary motion was not an accidental circumstance, but was accomplished by years of intense and nerve-wracking work, based on long series of observations which Kepler had inherited from his teacher, the famous Danish astronomer, Tycho Brahe.

In a very vivid way, "Troubadour of the Stars" portrays the struggle of Kepler for scientific accomplishment. As Imperial Mathematician (with salary unpaid for years) he attempted to fathom the laws governing the universe, while fighting against a turbulent background of religious wars, the deaths of his small children, and the harrowing trial of his mother as a witch. Saile has placed emphasis on the personal life of Kepler, rather than on the different steps to his scientific achievements.

The spirit of the book is well portrayed in a discussion between Kepler and Mästlin, one of his early teachers. " 'But is there anything stronger than truth?' Johannes asked with childlike guilelessness. 'There is!' shouted Mästlin, . . . 'It is stupidity'."

The book is written in a pleasant style, with bits of description, which are very pretty, having a continental flavour, such as the opening paragraph describing winter in Swabia, or the picture on page 70 of a monastery garden. The book was written before the start of World War II and makes rather uncanny reading at the present day, when scientists are still fighting against the background of war and pillage which surrounds them.

One of the most arresting passages in the book deals with his great work published in 1618.

> Under the spell of his visionary thoughts he put at the end of his work this hymn to the Almighty, toward whose face he felt impelled throughout his life:
>
> 'Let the sun and the stars sing the praise of the Creator and the harmonies of the heavens acclaim Him in jubilant tones, for everything comes from Him: the infinitesimally small part we know and that, too, which we do not know. I write my book for the present generation or for those to come. What does it matter? It will wait for its readers a hundred years.'
>
> He called upon the contemporary composers to write down the song of the heavenly spheres, and upon humanity to take an example from the eternal harmony of the universe. 'Abandon the discord of all enmities, all envy, all quarreling, and all dissension.' Before he put his work aside he entitled it: 'The Harmony of the Worlds'.
>
> But over Germany the fires of the great war were already burning.

Such a passage will inevitably fill a scientist with both pain and gladness—with pain, that after three hundred years science is still being pursued against a hideous background of war; with gladness, that in the past, in spite of war, famine, and pestilence, knowledge that has once been attained by mankind has endured.

H. B. S. H.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Meteor Observation in the U.S.S.R. in the Summer of 1941

Under date November 5, 1941, Mr. K. A. Voroschiloff of Moscow reports that Mr. V. S. Viskov at Stalingrad (Lat. 48° 42′ N., Long. $2^h\ 58^m\ 03^s$ E.) observed the meteoric shower π Cor. Bor. between June 25 and July 3. In this period 24 meteors were recorded and mapped during 11 hours 40 min. of observations (7 nights) in the region of Cor. Bor., Bootes, Serpens, Hercules and part of Draco. The chief radiant was in R.A. 236°, Dec. +31° (n=4) for June

29.82, and the same for June 25 and 26 (n=4). The brightness of the meteors was 2.5 mag. to 4.0 mag. (mean 3.2 mag.); no trains; duration 0.15 to 0.4 sec. (mean 0.25 sec.). The shower belongs to the "minor showers" formerly observed (R.A. 235°, Dec. +33°, π Coronids).

THE CONSTANT OF GRAVITATION

In recent years so much attention has been devoted to the mysterious cosmic rays, to metagalaxies, supernovae and other enormous objects at almost infinite distances, that the older problems relating to the all-pervading force of gravitation have been pushed into the background. It is a pleasure to see the announcement of a new determination of the "constant of gravitation." This may be defined as the attraction between two unit masses at unit distance apart. In the c.g.s. system if two homogeneous spheres, each of mass one gram, be placed with their centres one centimetre apart the force between them in dynes is the numerical value of the constant of gravitation. From it may be computed the mean density of the earth, as well as the mass of the sun and the planets.

The eccentric but extremely able Henry Cavendish in 1797-98 was the first to measure experimentally this constant. Indeed he inaugurated a new era in the measurement of small forces. Attaching a 2-inch lead sphere on each end of a light rod six feet long suspended at its mid-point by a fine wire, he brought up to these spheres two 12-inch lead spheres, each weighing 350 pounds, and by the torsion of the wire actually measured the mutual attraction between the large and small spheres. From 29 separate determinations he deduced that the mean density of the earth was 5.448. This "torsion balance" method has been used in several other experiments of high precision. In 1895 Boys of England with a much smaller apparatus, but admirably designed for its purpose, obtained a result which was widely recognized as of very high accuracy. His value for the "constant" was 6.658×10^{-8}, corresponding to a mean density 5.527.

In 1930 Paul R. Heyl, a physicist at the National Bureau of Standards at Washington, D.C., using an improved torsion balance, obtained the value 6.670, which was generally considered the best up

to that date. Dr. Heyl was not entirely satisfied, and after further refinements and the most meticulous care he now gives the value as 6.673×10^{-8}. His apparatus was so sensitive that the time of swing of the pendulum was altered when the position of a bottle of mercury on a shelf was changed. The value in dynes just given is equal to one 15-millionth of a gram-weight, which is one 350-thousandth of the attraction of the earth on a pound mass!

Deep Sea Diving

With the old-style diving suit a depth of 100 feet was a considerable achievement, but in recent years new apparatus has permitted much lower descents. In November 1933 newspaper reports stated that a new diving bell with a mechanical robot to pick up objects descended at Seattle 400 feet; and on November 30, 1937, it was stated that a diver went down 420 feet in Lake Michigan at Milwaukee. These distances were exceeded in salvaging the ship *Niagara*, sunk in June 1940 by enemy mines when some 27 miles out from Auckland, N.Z., on her voyage to Vancouver, B.C. There was on board gold valued at eight million dollars. This has been recovered by a Melbourne company in co-operation with the Australian Navy and the New Zealand Government. With some difficulty the ship was located, at a depth of 438 feet. Depths greater than 500 feet were reached when exploring the ocean floor, where many mines were seen, and 150 were recovered. The divers must have had an eerie feeling moving about in the eternal quiet of these great depths.

These extraordinary operations had special interest for the present writer. In the autumn of 1922, after observing the eclipse of the sun on the north-west coast of Australia, the Canadian party consisting of Dr. R. K. Young, the writer and two members of his family, travelled from New Zealand to British Columbia on the *Niagara*; and when she was lost one of the writer's friends, Rev. J. G. Inkster of Toronto, was a passenger. He was rescued but lost his baggage.

C. A. C.

MEETINGS OF THE SOCIETY

AT WINNIPEG

December 10, 1941.—The regular meeting of the Winnipeg Centre was held in Theatre "F", University Building. Mr. L. J. Crocker presided as the president, Mr. L. W. Koser gave the address of the evening.

The topic was "The Age of the Earth" and was illustrated with many excellent diagrams and pictures which Mr. Koser had made.

The "planetesimals" of the Chamberlin and Moulton hypothesis would (if we ascribe their origin to the constant formation of atoms in solar space by the various unions of electrons, protons and neutrons, instead of the one-time tidal disruption of the sun) supply the materials upon which a long-interval supercomet could feed and develop into a planetoid, or, with increasing growth, into a planet.

Eventually this mass would attain a rotating motion by the tangential contacts of accreting smaller masses, whose speed of approach would be greater on the side opposite the sun and thus determine the contra-clockwise motion of the planets. Such rotating motions would set up involute (indrawing) gravitational currents which would capture and hold an atmosphere of nitrogen and oxygen; while the explosion of accreting hydrogen would conceivably add to the water vapour in the upper reaches and, condensing, find its way to the surface, thus constantly augmenting our water supply.

The seismograph has taught us much regarding the zonal densities of the earth and we now believe that the density is nearly uniform for about 1900 miles and has a specific gravity of about half of the whole earth, or near 2.75 as against 5.52 for the earth as a whole; this is determined by the nature of the seismic waves anywhere within an arc of 104 degrees. This leaves a heavy gravitational core of about 4200 miles with a specific gravity of about twice the average.

As the interior of the earth contains all the constituents of every acid, as well as the catalysers, and, as it is not difficult to conceive of large re-action chambers existing in many places, it is a possibility that strong acids—sulphuric, nitric, and hydrochloric—are being constantly formed and, along with radioactive elements, are producing hot magmas and gases which work towards the surface and produce the geological disturbances that make for vulcanism, mountain building, continental rise and continental tipping.

It is conceivable also that these same agencies also attack the dense inner core of the earth, mulsifying and expanding its surface into materials of less density and forcing them outwards, thus expanding the earth's surface and forcing the continents farther apart. After prolonged expression of these energies, there would come a recession to stability in which there would be corrugation, folding and faulting at the earth's surface; and intrusion of epeiric seas, which

would last until the next continental uplift and receding would leave masses of salt water in closed valleys.

As soon as a mass of material rises above the level of the sea, the disintegrating and transporting agencies of nature start the work of returning it to the sea. Up to the line of perpetual frost, the activity of these agencies, which are alternating heat and frost, rain, growing roots, wind and drainage systems, increase in direct proportion to increasing height. The materials thus removed are carried back to the sea, some in solution, some in suspension and some moved mechanically by force of current. When they reach the comparatively still water they are sorted by gravity and settle to the bottom as "sediments", burying some of the existing plant and animal life, which, being metamorphosed through replacement of bone and tissue by silica, or lime, or both, become stone fossils or replicas in stone of every age of past life.

Thus these *sedimentary* rocks become *historical* rocks and tell us, not only about past plant and animal life, but record weather conditions; submergence and re-elevation of lands; relative heights of land, whether low and swampy with hot moist climate or high, dry and cool; periods of glaciation; dominance of different orders and the gradual evolution of plants and animals from the simple and primitive to the more complex, and leading right up to the beginning of man's appearance on the earth as evidenced by his remains and his artifacts.

The ability to read the leaves in this "Petrified Book of Nature" comes under the heading of historical geology and is a comparatively recent acquirement. It is just a little over one hundred years since William Smith, an English surveyor, mining and canal engineer, established the fact that the relative age of geological strata could be determined by the kind of fossils found in them and the sequence, of the strata by the sequence of the fossils. England is probably the richest of all countries in the variety of its geological formations and much of this is exposed at or near the surface as the result of tilting, faulting and erosion. Through and into these fossiliferous strata, Smith dug his canals and sunk his shafts. At first he was astonished and then intensely interested in the variety of the fossils that were exposed; and he then set himself delibertaely to collecting and classifying them, with full data as to the formations in which they were found. He collected some 200,000 fossils and produced a coloured geological map giving detailed information, and he further put forth the postulate that "similar range of fossils, no matter in what part of the world they may be found, denoted similar age of geological formation," although the formations themselves could differ according to local conditions.

Smith's hypothesis soon became an established fact and geologists the world over set themselves to collecting data wherever possible, then bringing their results together and co-ordinating them. The grand net result was to establish the fact that there existed some 529,000 feet of distinctly different strata.

This implied an immense passage of time but with no definite means of exact determination. It was thought, however, that it could not be less than an average of 1000 years for each foot of accumulation; the gradation in life changes making any estimate untenable that was less than that, and it might conceivably

be much more. This gave a minimum tentative estimate of 520 million years, which, compared to the computation of Bishop Ussher seemed staggering. (Ussher had computed from Bible chronology and secular history that the Universe was created in the year 4004 B.C.)

The geologists and biologists were, however, very much discouraged by the belief tenaciously held by Lord Kelvin and Hermann Helmholtz, that the sun owed its manifestation of energy to the fact that it was steadily contracting and that its life could not have been more than 100 million years and more probably not half that long. As both these men stood on the top rungs of mathematics and physics, it was not until their contentions were disproved that the question of great age came again to the fore.

The astronomer Edmond Halley had put forward the suggestion that if we could compute the total amount of salt in the oceans and then divide it by the salt added each year by all the rivers emptying into the oceans, then we could get a good approximation of the age of the earth. One notices here an interesting peculiarity, to wit, Bishop Ussher, who thought that he had settled the question of the age of the earth for all time died the same year that Halley was born,—1656; Ussher gave an age, not merely to the earth but to the whole universe, of less than six thousand years, while the postulate of Halley, later carried out by the physicist J. Joly, estimating from a mass of collected data and using sodium alone instead of its chloride, gave a minimum approximation of 81 million years for the accumulated salinity of the oceans, and this, it was later agreed, could have been multiplied by 60 or more, for hundreds of million of years had to pass before enough sodium could be dissolved from the igneous rocks to provide the salt contained in the oceans. Besides, there would be vast periods of time when drainage was at a minimum as against present drainage which is at or near a maximum.

Looking over the assembled data at the turn of the last century, it can be definitely stated that we had no idea of the age of the earth, and were besides very much confused by the many attempts to arrive at a conslusion; yet those who were convinced of its great antiquity were earnestly hoping for some development that would furnish conclusive evidence.

Then came the answer to their intense wish; or at least a sufficient answer to prove their contention that a vast period of time had passed in the accumulation of sedimentary strata and the evolution of plant and animal life as depicted in the secondary rocks. This answer was the ***radioactive time clock;*** something that had been ticking away at a uniform rate ever since the intruding igneous rock in which it was contained, had had its dispersing heat sufficiently reduced to permit the grouping and crystallizing of either one or both of the highly unstable elements, ***uranium*** and ***thorium***, both of which undergo changes at definite rates until they end their work as isotypes of lead, recording, by the amount of accumulated lead, the time that the clock has been ticking.

In fact it is a possibility that uranium and thorium are only formed under conditions of crystallization, for, if they had existed as isolated atoms or molecular groups for indefinitely long periods in the earth, then why would they not have

deteriorated or undergone transformation before they grouped as crystals? On the other hand it may be that only the unaltered parent element draws together to crystallize, leaving the altered parts variously distributed. However, we will leave this to the research chemist and work with the tools that are given us, which are highly valuable for our purpose. At the same time we are intrigued with the idea that an isotope of lead with an atomic weight of 206, might have, under conditions of crystallization, the property of attracting to itself 8 nuclei of helium and 10 electrons; while another isotope of lead with atomic weight 208, under similar conditions attracts 6 nuclei of helium and 8 electrons. Then each of these elemental systems, finding that they cannot hold on to the inert helium, are forced, through long and varied periods of time to let go of them one at a time. This idea gains some credence from the fact that the lighter atom of lead with the greater load of helium disintegrates almost three times as fast as the heavier atom of lead with the lighter load of helium.

Here you have some idea of the constituent parts of a radioactive element, and, for the general purpose of our talk, this would really suffice, but for the benefit of those who would like to understand the process a little better we shall go into a few details regarding the atom.

About 500 B.C., a Greek philosopher by the name of Leucippus, reasoned that "all matter was made up of extremely minute particles, invisible and indivisible". These he called *atoms* because they were *atoma*, that is, uncuttable, or not subject to further division; and these were the "building bricks" that by their union with each other in vast quantities and by their combinations in stable compounds, made up all matter that existed. His pupil Democritus, enlarged this into a creative system for the whole universe.

This idea of the ultimate atom gained general recognition among contemporary philosophers and held until the time of Plato who also believed in it and wrote about the different shapes of the atoms. In fact the properties of the atoms were supposed to reside in the special shapes assigned to each; and only one of these philosophers, Anaxagoras, suggested different chemical properties for each atom. But this seemed too far advanced for acceptance. The idea of assigning geometrical shapes to the different atoms probably had its inception from the observed crystallization of different minerals.

With the passing of Plato, the atomic idea went into seclusion; although there were sporadic attempts to revive it. The reason may be traced to several causes. First, the great Aristotle, who dominated the intellectual world during his time and for about 1500 years afterwards, refused to accept it and revived instead the concepts of Manu, the early Sage of India, who held that fire, water, air and earth were the fundamental elements. Second, there was no instrumental help, no knowledge of chemistry other than experimental mixing and melting. Third, knowledge was only in the hands of a few, who were too isolated in time and locality to work in conjunction. Fourth, the civilized world was being overrun by the Roman military party, who, like the German military party, worshipped the ideal of conquest, and pure science produces only withered blossoms under the heel of military dictators.

Of these obstructing causes, the greatest was, we believe, the veto of Aristotle. We know now, and he undoubtedly knew then, that he was wrong. Why then did he arbitrarily turn thumbs down on the atomic concept? The answer probably lies in the nature of the man himself. His great intellect was counterbalanced by stubbornness and jealousy; he preferred to give credit to no one but himself; he especially declined to give credit to any ideas put forth or entertained by Plato, who had been his teacher for nearly twenty years. His apparent refusal to apply his great analytical mind to a disinterested examination of this concept might be explained by the fact that it was accepted by Plato.

Why do we bother about his decision at this late date? It is because we believe that, had he decided in favour of the atomic theory, the Greeks of Athens and Alexandria might have pursued the subject with the same thoroughness that characterized their other achievements and have anticipated much that is known to-day, with the result that we could have been that much further on. As it was, the atomic theory practically went into oblivion for over 2000 years, or to the end of the eighteenth century, when a great awakening interest in analytical chemistry gave it its first real chance to survive, for here was the opportunity to put it to practical use; though it was not until the beginning of the nineteenth century that John Dalton, an English teacher of chemistry and physics, set it upon a foundation that has been growing stronger each year. Dalton found that compounds of chemical elements could only be made in definite and in full multiple proportions, regardless of how minute were the quantities used, and he reasoned that this union took place between the ultimate "invisible and indivisible atoms" of Leucippus. Dalton also worked out a rough, but inadequate, chemical formula, which was later improved on by the Swedish chemist J. J. Berzelius (d. 1848) who agreed with the suggestion of Sir Humphry Davy (d. 1829) "that the union of the atoms was effected by electrical charges on them."

In 1815 a remarkable hypothesis (remarkable for this early date) was put forward by an English physician, Dr. William Prout: That "all atoms were possibly just multiple combinations of the simplest atom, hydrogen". This seems to have been the first conception that all atoms, other than hydrogen were not ultimate particles but compound systems. We know to-day that even the hydrogen atom is not an ultimate particle.

Time does not permit us to go into the details of each important contribution towards our present concept of the atom, but along that gradually widening road are monuments to such men as: Michael Faraday, Hermann von Helmholtz, James Clerk Maxwell, Sir William Crookes, J. J. Thomson, Svante August Arrhenius, Henri Becquerel, Madame Curie, Lord Rayleigh, Lord Rutherford, Frederick Soddy, Robert A. Milliken, F. W. Aston, James Chadwick, Carl Anderson, Arthur Holmes, B. B. Boltwood and others. Their names are legion and are growing larger as research continues.

As a result of all this research, we know to-day that the atoms are not ultimate indivisible particles but are composite systems ranging from two constituents for normal hydrogen to 330 (at least) for uranium. The number of different

constituent parts is surprisingly small; three only are positively known and one, two or three others may be included.

The known parts are: 1st. The ***electron***, carrying a negative electric charge and having a mass of 9×10^{-28} grams. This is regarded as the unit of *electricity*. 2nd. The ***proton***, carrying a positive electric charge and having a mass about 1840 times the mass of the electron. One proton and one electron make up the atom of hydrogen. 3rd. The ***neutron***, carrying, as the name implies, no electric charge and having a mass approximating that of the proton.

The conjectured parts are: 1st. The ***positron***, carrying a positive charge of electricity, having a mass the same as the electron and possibly, with the electrons, making up the comparatively heavy mass of the protons and neutrons, accordingly as the combining number is odd or even. 2nd. The ***neutrino***, still indefinite but assumed to have no charge and to have the same mass as the electron and positron. This might possibly be the unit of the hypothetical ether. 3rd. The ***mesotron***, carrying a negative charge and having a mass intermediate between the electron and proton; still in an indefinite stage. With the known parts we can build up all the atoms into what constitutes a good working theory, and upon analysis by bombardment this theory appears to be checked by facts and enables us to get a fairly good understanding of the phenomena of ***radioactivity***. The conjectured parts may have their place in final analysis of protons, neutrons and isotopes.

We shall now consider the constituent parts of four atoms that have a bearing upon the phenomenon of radioactivity, these are:

1st. *Hydrogen*. This consists of two of the known parts; a proton, acting as a nucleus, and a free moving electron. This is the simplest of the atoms but sometimes one or more neutrons will somehow attach themselves to the nucleus to form "heavy hydrogen". Hydrogen is very explosive. Atomic weight, 1.

2nd. *Helium*. The atom of helium is made up of two protons and two neutrons to form the nucleus and it has two free moving electrons; but, the nucleus is peculiar in that the two protons and the two neutrons seem to form one combined particle, or radical, which cannot be separated by ordinary chemical reaction; this combination has become known as the *alpha* particle and in itself carries a double positive charge of electricity. This alpha particle must be kept in mind for a better understanding of radioactivity, or at least of the process of disintegration known by that name. Helium is normally an inert gas and can only be made to combine chemically under the influence of electricity. Atomic weight, 4.

3rd. *Uranium Lead*. This lead, while chemically the same as ordinary lead, differs from it in its atomic weight; ordinary lead having an atomic weight of 207.2, while the atomic weight of uranium lead is 206. The atomic number of each being 82. Uranium lead therefore has 82 free electrons and a nucleus consisting of 82 protons and 124 neutrons; but as we have shown that two protons and two neutrons tend to combine and form an alpha particle, then we can, in theory at least, redistribute the nuclear content into 41 alpha particles and 42 neutrons, which still adds up to 206. The alpha particle, known also as the

helium nucleus, is not peculiar to helium alone, as it has been discovered in other elements; carbon for instance when intensely heated, as in powerful carbon lamps, has been shown to give off alpha particles.

4th. *Uranium*. The atom of this element consists of the above uranium-lead atom to which is added 8 alpha particles and 10 electrons. This gives it an atomic weight of 238 and atomic number 92. We may not be justified in stating its composition in this way but that is what it adds up to. This uranium unit, or let us continue to call it an atom; even though it is a vast collection of atoms, is unstable and breaks down into a succession of simpler elements until it ends up in uranium lead, called *radium G*. And it is this breaking down, which is purely spontaneous and cannot be effected by any external cause, that is called radioactivity; the breaking down consists of throwing off, one at a time, the 8 alpha particles and the 10 electrons, with concurrent emission of extremely short-wave energy sparks called *gamma rays*. During the process of breaking down, the alpha particles collect electrons (which are everywhere) and helium is formed, which, being an inert gas, continues to stay with the parent metal uranium, although in long geological periods, some of it is bound to be separated.

Further, as the atom undergoes this succession of changes, new elements having different atomic weights and property numbers come into existence; among these are *ionium*, *radium* and *radon*; and when the changes have been completed there is left the atom of *uranium lead* which is stable. The percent of this accumulated lead multiplied by an established constant (7600 million years) gives the time that has elapsed since the uranium was formed, usually in pegmatite dikes at the top of intruding batholiths. The formula is Pb/U$\times$7600 million years. This method is known as "The Uranium Lead Ratio" or the "Geological Time Clock" and has been checked and rechecked by every doubting geophysicist, with the result that, while there are some variations as to final figures, the principle itself is not in doubt and there is a general concurrence in its acceptance as the only reliable method of obtaining approximately true ages of the rocks and therefore of geological time.

The basis of these calculations was established by Lord Rayleigh early in this century, who determined the rate at which the helium gas was formed. After three months of careful research he obtained a measurable amount and was able to state that "it would take *one gram of uranium nine million years to produce one cubic centimetre of helium.*" As the weight of helium at zero centigrade and at normal pressure is 0.1785 gram per litre or 0.0001785 gram per c.c., it became possible by using the chemical equation:

238 parts of uranium yield 206 parts of uranium-lead and 32 parts of helium, to determine the amount of the more reliable uranium-lead that would be yielded by one gram of uranium in one million years and also the total time of disintegration. This was set by Prof. Arthur Holmes of Durham University at 7400 million years, but the committee set up by the United States Geological Survey to investigate the question of the age of the earth decided on the calculation of Prof. Alois F. Kovarik who set the figure at 7600 million years and Holmes later adopted this figure as it was in reality a fair check upon his own.

Possibly, in the loose manner in which we have presented this, one might get the impression that it is a simple problem and that there is no excuse for variations; but in reality it is a very complex problem, entailing a tremendous amount of analytical work, and unless two workers on the same sample constantly check each other there is bound to be some variation. We, who are only interested in the results from an educational standpoint and are not competent to criticize, are glad to accept the generally agreed results.

For the sake of simplicity we have not gone into details regarding *thorium*, the other parent radioactive element, but the physicist has to consider this and its much longer period of disintegration (almost three times as long) and in the examples which follow a percentage of thorium enters into each one.

Mineral	Location	Geological Age	Lead Ratio	Calculated Age
Brannerite	Idaho, U.S.A.	Late Oligocene	0.005%	35 million years
Pitchblende	Colorado, U.S.A.	Early Eocene or late Cretaceous	0.008	60 " "
Pitchblende	Czecho-Slovakia	Early Permian	0.028	205 " "
Uraninite	N. Carolina, U.S.A.	Carboniferous	0.033	240 " "
Uraninite	Connecticut, "	Late Devonian	0.039	290 " "
Uraninite	" "	Silurian?	0.052	375 " "
Pitchblende	Katanga, Africa	Pre-Cambrian	0.081	575 " "
Broggerite	Norway	" "	0.125	900 " "
Uraninite	Black Hills, S.D.	" "	0.216	1460 " "
Monazite	Huron Claim, Man.	" "	0.300?	1830 " "

The oldest known igneous rock so far discovered is in the Karelian district of Russia to which is assigned an age of 1850 million years but we do not have the analysis. As all these igneous rocks intruded themselves up into previous sedimentary rocks, which were necessarily older, and as a vast period must have intervened between the original formation of the earth and these sedimentary rocks, we feel justified in saying that our earth cannot be less than 3000 million years old and many be considerably more.

January 14, 1942.—The regular meeting of the Winnipeg Centre was held in theatre "F" University of Manitoba. The president, Mr. L. W. Koser, was in the chair.

A lecture on "The Temperature and Source of the Heat of the Sun" was given by Prof. W. A. Anderson. He commenced by stating that the sun's energy would in a year melt a shell of ice 424 ft. thick with a diameter of 186,000,000 mi. The weight of this ice would be 4×10^{23} tons. Since 1838 when Pouillet constructed a pyrheliometer this energy has been measured several times. He found that energy received from the sun to be 1.736 calories per sq. cm. per min. More recent determinations by the Smithsonian Institution depend upon

an improved pyrheliometer. The thermocouple and thermopile have changed the figure to 1.937 calories per sq. cm. per min. By using this number to calculate the total sun's energy at 93,000,000 mi. or 149,560,000 km. the "astronomical" figure of 3434×10^{24} calories per min. was found.

Stefan's law of radiation, even by supposing the sun's surface to be a perfect radiator (which it is not) gives the temperature at the surface of the sun as 5750° Absolute. Temperatures up to 7000° A. perhaps would be more nearly correct.

Paleontologists agree that the earth's temperature has been fairly constant since the period of fossil deposits. This precludes that the considerable source of energy in the sun is caused by chemical action. And even sun-spots which have a temperature of 6000°C. are too hot for chemical combinations to exist.

In 1853 Helmholtz gave the world his theory of energy by the sun's contraction. By his calculation the age of the earth would be about 7,000,000 years. This we know to be inadequate in the light of present knowledge. The radio-active theory of sun's energy would assume that the sun contains a far greater proportion of radio-active substances than we have on earth. This is not believed. In 1932 Cockcroft and Walton of Cambridge used 500,000 volts (later they found that lower voltages would give the same results) to shoot hydrogen nuclei, that is protons, against a lithium target. They obtained alpha particles (helium nuclei) with greater energy than the original protons had.

	H	+	Li	yield	He	+	He
or	1.0076	+	7.0164	"	4.0028	+	4.0028
that is			8.0240	yields	8.0056		

There had been a loss of mass of .0184 which had been changed into energy. In this way 1 gram of any substance is equivalent to 34,000,000 horsepower-hrs. If protons and neutrons to the total mass of 1 gram unite in a nucleus to form heavier atoms, the small reduction in mass of .0023 gram would liberate approximately 200,000 kw.-hrs. of energy. Just before the outbreak of the present war two Germans bombarded uranium 235 with slow-moving neutrons. The resulting explosions produced thirty different elements and gave the enormous energy of 2,500,000 times as much as the same mass of coal. The terrific heat in the sun is enough to make the nuclear reactions self-sustaining. At 18,000,000°C. to 20,000,000°C. this would account for the entire solar radiation.

A summary of the structure of the sun follows:

Depth	*Temp.*	*Specific gravity*
1/6 sun's radius	1,070,000°C.	.0045
1/2 " "	5,250,000	.92
3/4 " "	13,000,000	24.6
88% " "	25,700,000	110.

The centre of the sun would still be gaseous but would have nuclei stripped of all or nearly all their electrons.

OLIVE A. ARMSTRONG

February 11, 1942.—The regular meeting of the Centre met in Theatre "F", University of Manitoba. The president, Mr. L. W. Koser, was in the chair.

Prof. H. H. Saunderson, the speaker of the evening chose "The Atom" as his topic. He began by tracing the early theories of matter. As early as 1000 B.C. it was suggested matter could be subdivided. In 600 B.C. Thales thought water, or wetness, was the fundamental element. Anaximenes added air; Heraclitus in 500 B.C. added fire and in 350 B.C. Empedocles added earth as the fourth element. In 375 B.C. Democritus stated that matter could be broken into atoms and that love and hate were forces which could change matter. Aristotle rejected the idea of the four elements or atoms. He said matter was infinitely divisible; composed of a quintessence, hyle, which had properties of hotness, wetness, etc. The alchemists from 1000 A.D. added other properties, as blackness, liveliness, lustre, malleability, hardness, saltness.

Francis Bacon reintroduced the atom idea. Boyle came close to the present concept of elements and compounds. By 1800 Dalton had given the world his famous atomic theory. He assumed that similar atoms made the molecule and that the atom could not be divided. In 1825 Proust suggested the atom could be divided and might be made of hydrogen.

The modern history of the atom has covered the last fifty or sixty years. By using vacuum tubes the cathode particle or electron was made to do work. This negative particle was found to approximate $\frac{1}{2000}$ the weight of the hydrogen atom. As all gases gave the same result it was thought that all matter had a base of electrons. By using another type of vacuum tube with a canal from the anode it was found that these positive rays differed for each element used.

Radio-activity, as discovered by Becquerel and the Curies, was a tremendous addition to the knowledge of the atom's behaviour. Radium was found to give off straight radiations, if not interfered with, but in an electric field they broke up into three different streams. These were named "alpha", "beta" and "gamma" rays. The remaining matter was not all radium. Eight different elements gave these same emanations. All matter has negative electrons but as some matter seems neutral it must have positive matter too.

Lord Rutherford, by experiment, proved that an atom is like a tiny solar system having a positive nucleus at its centre, surrounded by negative electrons which move about it as if by centrifugal force. The nucleus is about the size of 10^{-13} cm. Bohr determined that the electrons had regular orbits about their nucleus. When these electrons change to a larger orbit they absorb energy but when they change to a smaller orbit they liberate energy. It is now thought that these positive protons and negative electrons are not matter but energy, so Aristotle's belief of centuries ago is perhaps not far from modern theory.

Many questions added to the interest of this lucid lecture.

OLIVE A. ARMSTRONG.

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